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| Q# | points | Reasons for possible point deductions | Excellent Answer (Full points) |
| Q1 | 0.5 | There are not 3 well-articulated differences. The observations are short or not well thought out. An example of a poor answer is a simple statement that the cell sizes are different are something that is not related to an actual on the ground feature but rather a description of the rasters themselves. The pixels are also not colored by intensity of return but by elevation. | Three observations that relate to geological, ecological, or human-made features that can be differentiated by height. Examples are observations that in the 1m streets can be seen as well as the smaller stream channels. Discussing that elevation gradients are defined with a higher level of precision in the 1m. |
| Q2 | 0.5 | The answers don’t relate specifically back to the examples given in question 1, or they are very short and don’t relate consequences to precision in height measurements. | Often the issues with higher resolution data relates with co-registration of multiple scans or the actual size of the data. Benefits of lower resolution data is that processing times can be faster if coarse resolution is fine. If relating topography to something with very coarse resolution like landsat images, high resolution data may not be needed, and coarser data is often more easily accessible with an older available archive. |
| Q3 | 0.25 | If the screen shot is not a colored hillshade or of low quality. The caption is not well developed or missing. | Any part of the DTM rendered in an interesting way. The caption is descriptive of the scene. |
| Q4 | 0.5 | One or both of the screenshots are missing or low quality. | Any screen shot of the trace downstream and watershed tool is acceptable |
| Q5 | 0.5 | No justification for the cell height used or justification is very sparse.  Not relating the increase in cell size to a loss in topographic detail. | Using the minimum, maximum, or average value is acceptable as long as there is a well developed justification for the use.  If interested in effects like shading or view shed, maximum values may be the preferred values.  If looking for depressions or locations where water may drain to, minimum values may be most appropriate.  Increasing the pixel size will remove topographic detail. If may not seem that significant if you increase from 1 foot to 1 meter, but consider that a lot of satellite imagery is 30m resolution. If you increased the grid step size to 30m, you would likely be erasing entire stream channels, however, you may want to get an average elevation value of a 30m square to match to Landsat imagery.  If you have a large area, fine spatial resolution may not be needed and may be overly computationally taxing for the job needed. |
| Q6 | 0.25 | The screenshots are low quality or very zoomed out so the change in the features is not obvious.  The screenshots are not of the DTM but a DSM. | Two screen shots. One of 1m resolution, and the other 10m resolution. The screen shot should be fairly zoomed into a feature so the change in the quality is readily apparent. |
| Q7 | 0.5 | Not relating the spatial resolution to stream channel delineation. | With a decreased spatial resolution, stream channels will become less defined. General flow direction may not be changed, just the actual path of a stream could become completely undetectable if the pixel size was large enough. This would especially impact stream channel delineation when roads or bridges are in the area. |
| Q8 | 0.25 | The units are not identified as the element that is different between the two projections or that this change in units is what causes the boundary values for 2927 to be so much bigger. | The change between 2927 and 2856 is the units. 2927 is feet and 2856 is meters. The bounds for 2927 are much larger. For example a boundary on 2856 is 34502.33. If we multiply the boundary value by 3.28 (conversion from meters to feet), you get the boundary value for 2927 (~113167). Conversion from one projected coordinate system to another can be very simple. |
| Q9 | 0.25 | Something other than 3740 | 3740 |
| Q10 | 0.25 | The descriptions are only partial.  Copy and paste is acceptable . | Knnidw: This function is made to be used in rasterize\_terrain or lasnormalize. It implements an algorithm for spatial interpolation. Interpolation is done using a k-nearest neighbour (KNN) approach with an inverse-distance weighting (IDW).  Tin: This function is made to be used in rasterize \_terrain or lasnormalize. It implements an algorithm for spatial interpolation. Spatial interpolation is based on a Delaunay triangulation, which performs a linear interpolation within each triangle. There are usually a few points outside the convex hull, determined by the ground points at the very edge of the dataset, that cannot be interpolated with a triangulation. Extrapolation is done using the nearest neighbour approach.  Kriging: This function is made to be used in rasterize \_terrain or lasground. It implements an algorithm for spatial interpolation. Spatial interpolation is based on universal kriging using the krige function from gstat. This method combines the KNN approach with the kriging approach. For each point of interest it kriges the terrain using the k-nearest neighbour ground points. This method is more difficult to manipulate but it is also the most advanced method for interpolating spatial data. |
| Q11 | 0.3 | Copying and pasting from the r documentation is OK as long as the values of 6 and 2 are discussed as well. | K=6 denotes that there are 6 nearest-neighbors  p=2 denotes that this algorithm is using a power of 2 for inverse distance-weighting. |
| Q12a&b | 0.5 | The screenshots are low quality or missing titles.  Some statement about change is needed, even if it is as simple as “the look the same” | The plots look nearly identical. Stating that there is no visible difference is acceptable or discussing small changes is also acceptable |
| Q13 | 0.5 | Not relating the x and y axes as coordinates with units in feet. | The x and y values are the coordinate information. In this case Washington StatePlane South. The units are in feet. Because this is a projected coordinate system, and not a geographic coordinate system, x and y are spaced evenly in a grid.  This is very different than latitude and longitude. |
| Q14 | 0.5 | Missing screenshots, or screenshots are of low quality.  Both differences and similarities must be described.  One does not need to be determined to be “best” but reasoning must be present as to witch one is best or why neither is “best”. This is a subjective answer but needs to be defended. | One of these models is not “best” but understanding the differences that the different algorithms produce is what is important.  As long as the responses are well articulated in how they both differ and are similar, full credit. |
| Q15 | 0.25 | A simple yes or no answer is given.  Backing up your answer with a reasonable justification is necessary. | Yes they are good representations, or no they are not, are both acceptable answers. Once again, the justification for your answer is needed.  Yes they are good representations as they delineate stream channels and relatively small topographic changes.  No they are not good representations as they are still a simplified model of the ground. Many elements relevant to micro topography habitat are not being captured… |
| Q16 | 0.5 | Citation is missing or is incomplete. Need the title and not just author / year  The ability to trace back the algorithms used for the functions is incredibly important.  The intention is to not have you just copy and paste code and magic things happen, but be able to trace back to the source for a fuller understanding of the algorithms. | Zhang, K., Chen, S. C., Whitman, D., Shyu, M. L., Yan, J., & Zhang, C. (2003). A progressive morphological filter for removing nonground measurements from airborne LIDAR data. IEEE Transactions on Geoscience and Remote Sensing, 41(4 PART I), 872–882. http:#doi.org/10.1109/TGRS.2003.810682.  W. Zhang, J. Qi\*, P. Wan, H. Wang, D. Xie, X. Wang, and G. Yan, “An Easy-to-Use Airborne LiDAR Data Filtering Method Based on Cloth Simulation,” Remote Sens., vol. 8, no. 6, p. 501, 2016. (http://www.mdpi.com/2072-4292/8/6/501/htm) |
| Q17 | 0.5 |  | ws: numeric. Sequence of windows sizes to be used in filtering ground returns. The values must be positive and in the same units as the point cloud (usually meters, occasionally feet).  th: numeric. Sequence of threshold heights above the parameterized ground surface to be considered a ground return. The values must be positive and in the same units as the point cloud. |
| ~~Q18~~ | ~~0.3~~ | ~~Not all six are identified or the descriptions are not included.~~ | ~~‘sloop\_smoothlogical. When steep slopes exist, set this parameter to TRUE to reduce errors during post-processing.’~~  ~~‘class\_thresholdscalar. The distance to the simulated cloth to classify a point cloud into ground and non-ground. The default is 0.5.’~~  ~~‘cloth\_resolutionscalar. The distance between particles in the cloth. This is usually set to the average distance of the points in the point cloud. The default value is 0.5.’~~  ~~‘rigidnessinteger. The rigidness of the cloth. 1 stands for very soft (to fit rugged terrain), 2 stands for medium, and 3 stands for hard cloth (for flat terrain). The default is 1.’‘iterationsinteger. Maximum iterations for simulating cloth. The default value is 500. Usually, there is no need to change this value.’~~  ~~‘time\_stepscalar. Time step when simulating the cloth under gravity. The default value is 0.65. Usually, there is no need to change this value. It is suitable for most cases.’~~ |
| Q18a&b | 0.5 | Screen shot is missing or of low quality.  The discussion about the “spikes” needs to mention key phrases like: “misclassified”. “non-ground” “tree points” “mesh” “sheet”  A well-articulated response that discusses how the misclassified points force the mesh or “sheet” to form spikes. | The settings that were used in the PMF classified some non-ground points as ground. Points that were higher on the trees. This was likely due to the window size being too small and got into an area without enough actual ground points present. This isn’t to say that PMF doesn’t work, only that the settings that were used need to be changed.  With points with a higher Z value included into the triangulation for the ground model, the mesh that is laid over the points gets pushed up to include the non-ground points and creates those spikes. |
| Q19 | 0.25 | Screenshots are missing or of low quality. |  |
| Q20 | 0.5 | Not relating point density and coverage directly with canopy cover and observing that wholes in data where heavy canopy has occluded all lidar returns, can cause significant issues with ground models. | Canopy cover relates to ground model quality in that sparser canopies allow more lidar pulses to hit the ground, and with more points to use, ground models will be more accurate. The “holes” that can be caused if heavy canopy intercepts all lidar returns can make the ground point classifiers think that the dense canopy layer is the ground. |
| Q21 | 0.5 | Missing one element either topography or canopy cover. | Low density is fine in areas with little vegetation and a generally flat topography. Short sagebrush, desert, agricultural fields. A high density point cloud is more needed for areas with dense canopy and lots of topography. An extreme example of this would be the Olympic peninsula. |
| BONUS | 0.5 | A mix of DTMs and Hillshades for the screenshots submitted.  The comparison between the vendor supplied and products you produced yourself through two very different approaches. For a lot of analysis, a high resolution DTM may not be needed, but hopefully you understand how the processing steps can create small differences and if using a DTM for research, you should know what p rocess was used to create it.  **Add if correct** | 3 screen shots. A hill shade would be best to detect differences but not required. For the comparison, either all DTM or all hillshades should be used. Visible differences may not be obvious and stating as much is acceptable. Zooming way in, differences become more obvious. |
| GRAD STUDENTS\* | 1 | Lines are not fully commented.  One or more lines is missing in the code.  **\*subtract if wrong** | Ideally a setwd and packages will be installed and loaded in the script provided. Also a write command should be included but not required.  See screenshot below |

Text, letter

Description automatically generated